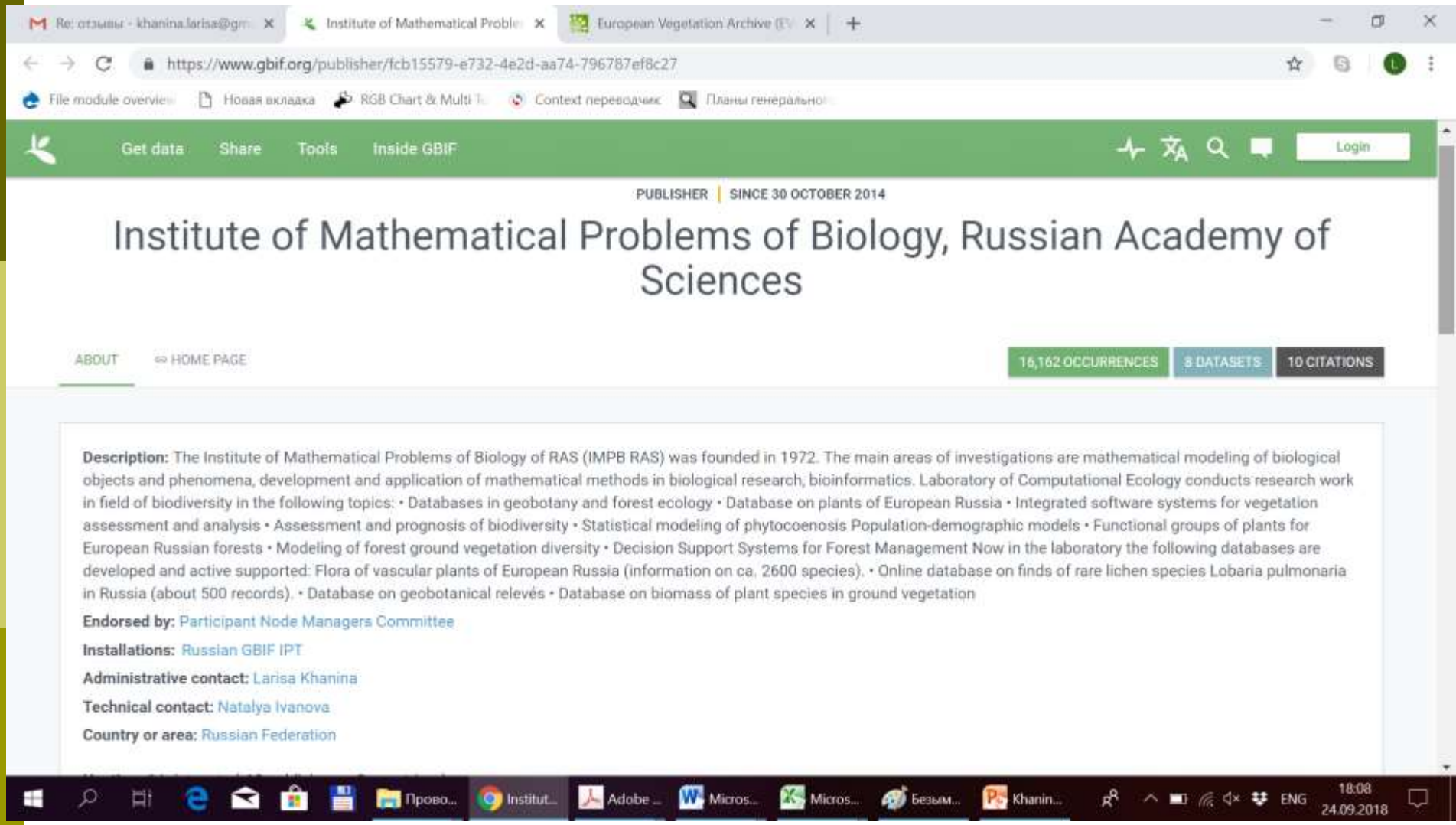
Plant functional groups for carbon and nitrogen cycle modelling and diversity estimation in boreal forest ecosystems

Larisa Khanina, Maxim Bobrovsky, Vadim Smirnov, Mikhail Romanov, Natalia Lukina

Institute of Mathematical Problems of Biology RAS - branch of the M.V. Keldysh IAM RAS
Institute of Physico-Chemical and Biological Problems in Soil Sciences of RAS
Center for Forest Ecology and Productivity of RAS

ICEI-2018, Jena

khanina.larisa@gmail.com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Description: The Institute of Mathematical Problems of Biology of RAS (IMPB RAS) was founded in 1972. The main areas of investigations are mathematical modeling of biological objects and phenomena, development and application of mathematical methods in biological research, bioinformatics. Laboratory of Computational Ecology conducts research work in field of biodiversity in the following topics: • Databases in geobotany and forest ecology • Database on plants of European Russia • Integrated software systems for vegetation assessment and analysis • Assessment and prognosis of biodiversity • Statistical modeling of phytocoenosis Population-demographic models • Functional groups of plants for European Russian forests • Modeling of forest ground vegetation diversity • Decision Support Systems for Forest Management Now in the laboratory the following databases are developed and active supported: Flora of vascular plants of European Russia (information on ca. 2600 species). • Online database on finds of rare lichen species Lobaria pulmonaria in Russia (about 500 records). • Database on geobotanical relevés • Database on biomass of plant species in ground vegetation
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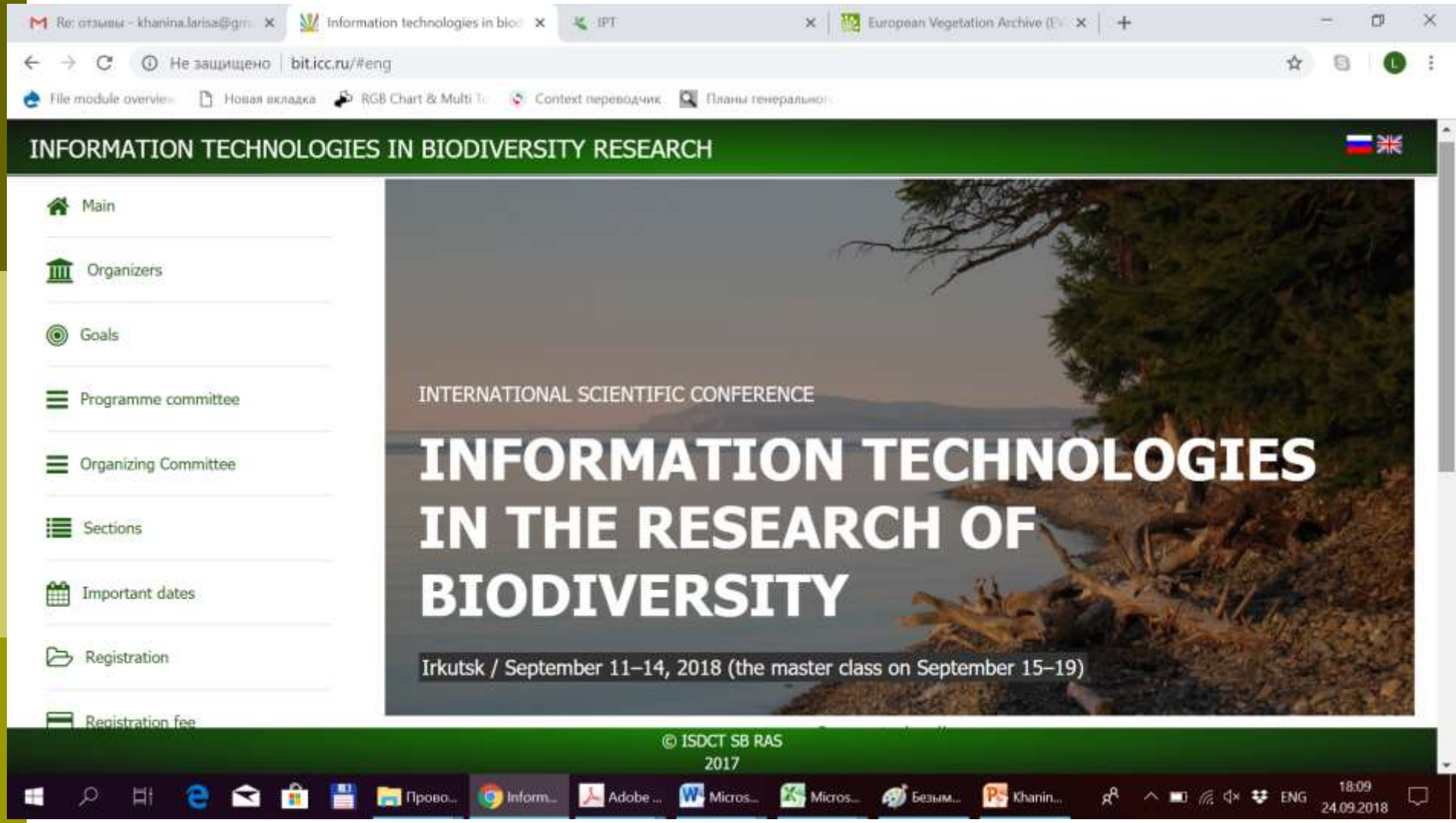
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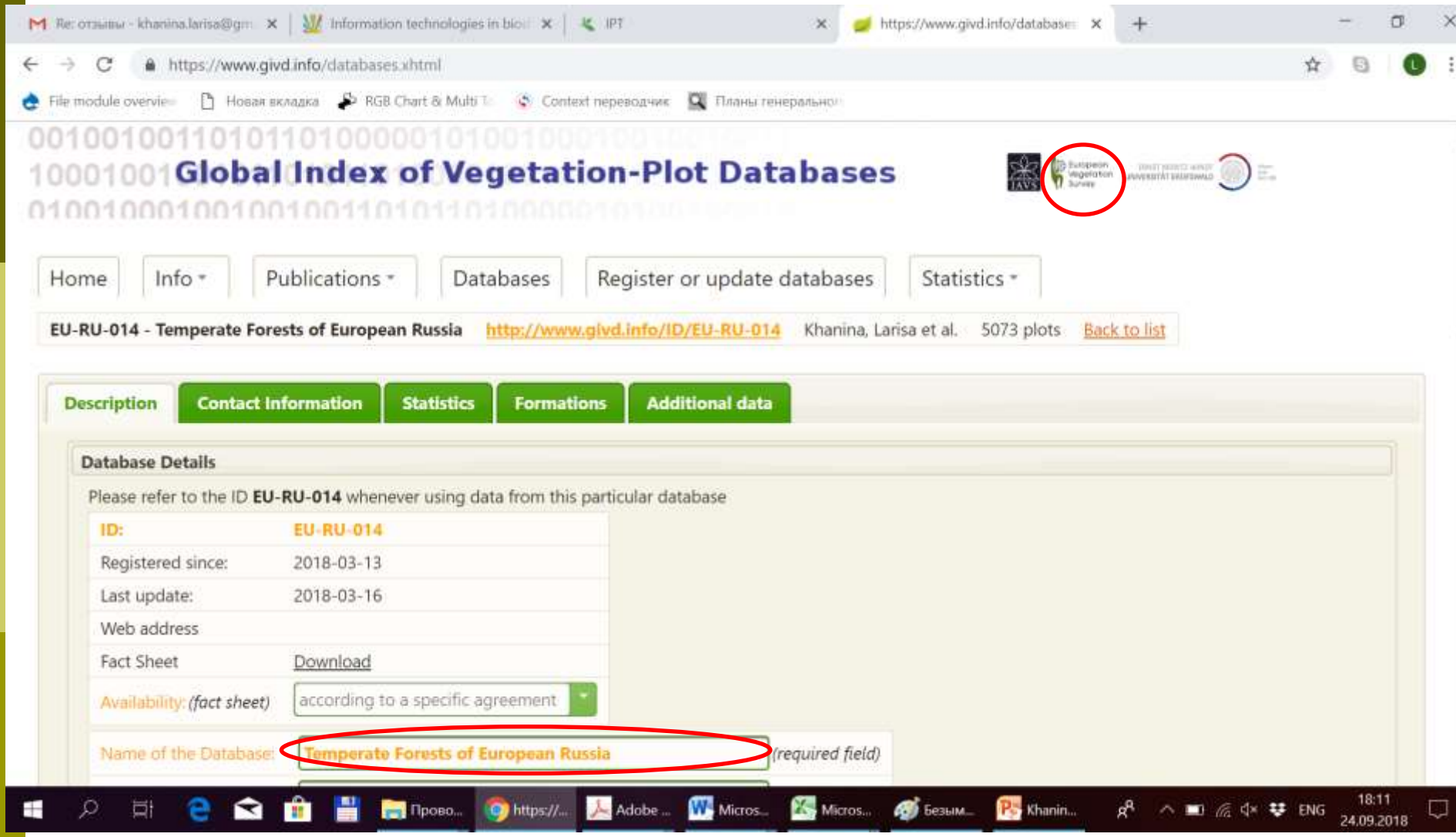
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EU-RU-014 - Temperate Forests of European Russia
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Khanina, Larisa et al.
5073 plots
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Statistics
Formations
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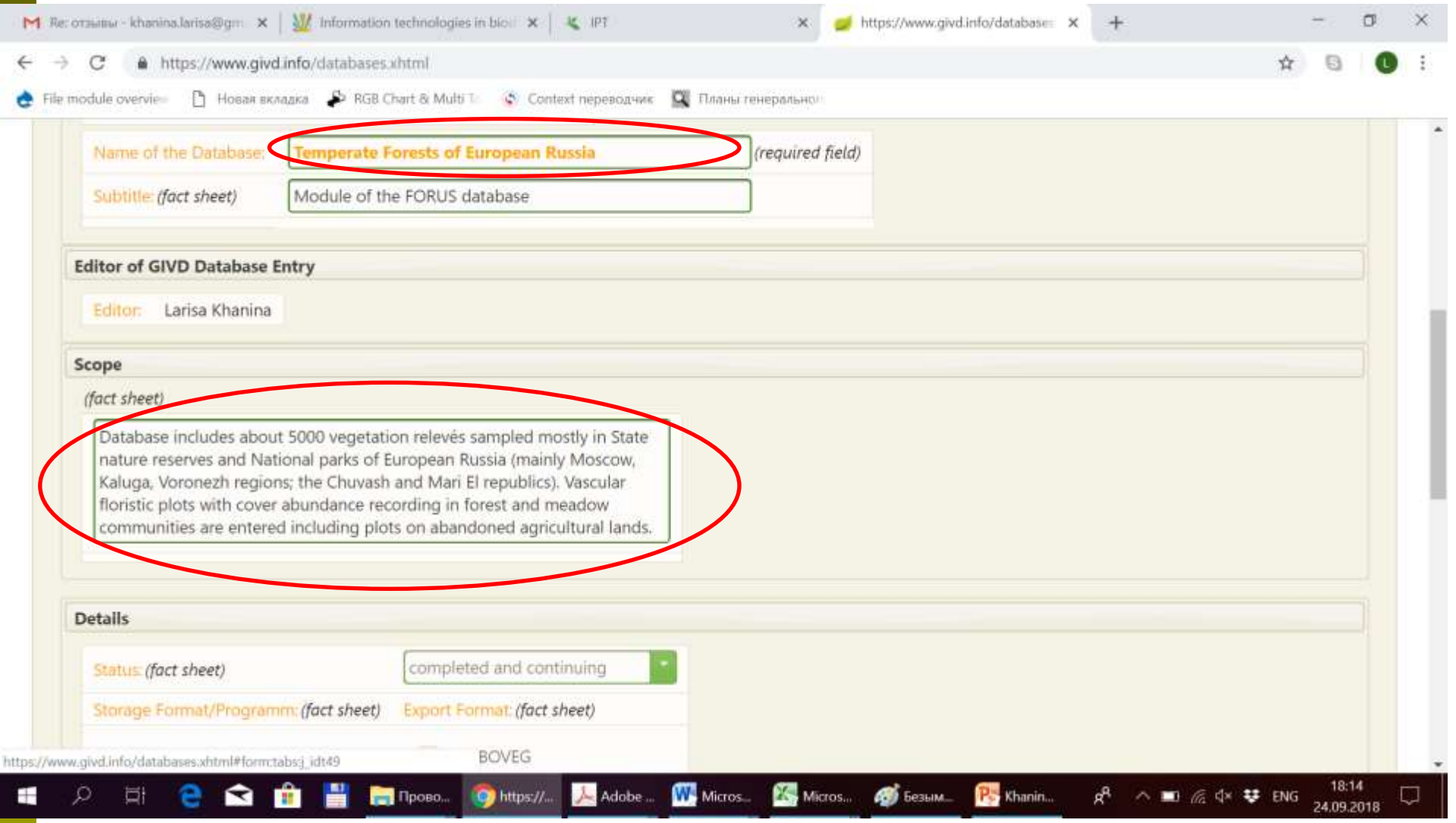
Database Details
Please refer to the ID EU-RU-014 whenever using data from this particular database
ID: EU-RU-014
Registered since: 2018-03-13
Last update: 2018-03-16
Web address
Fact Sheet Download
Availability: (fact sheet) according to a specific agreement
Name of the Database: Temperate Forests of European Russia (required field)


https://www.givd.info/databases.xhtml
Name of the Database: Temperate Forests of European Russia (required field)
Subtitle: (fact sheet) Module of the FORUS database
Editor of GIVD Database Entry
Editor: Larisa Khanina
Scope
(fact sheet)
Database includes about 5000 vegetation relevés sampled mostly in State nature reserves and National parks of European Russia (mainly Moscow, Kaluga, Voronezh regions; the Chuvash and Mari El republics). Vascular floristic plots with cover abundance recording in forest and meadow communities are entered including plots on abandoned agricultural lands.
Details
Status: (fact sheet) completed and continuing
Storage Format/Programm: (fact sheet) Export Format: (fact sheet)
BOVEG

Plant functional groups for carbon and nitrogen cycle modelling and diversity estimation

Ground vegetation layer = field layer
(herbs, grasses, dwarf shrubs, etc.) +
bottom layer (mosses, lichens)

Ecological-coenotic groups (ECG) of plants

Nemoral – species of broad-leaved forests

Boreal – species of dark-coniferous forests

The ECG list is accessible by

http://www.impb.ru/index.php?id=div/lce/ecg&lang=eng

Piny – species of pure *Pinus sylvestris* forests

Meadow-edge species

Nitrophilous – species of *Alnus glutinosa* forests

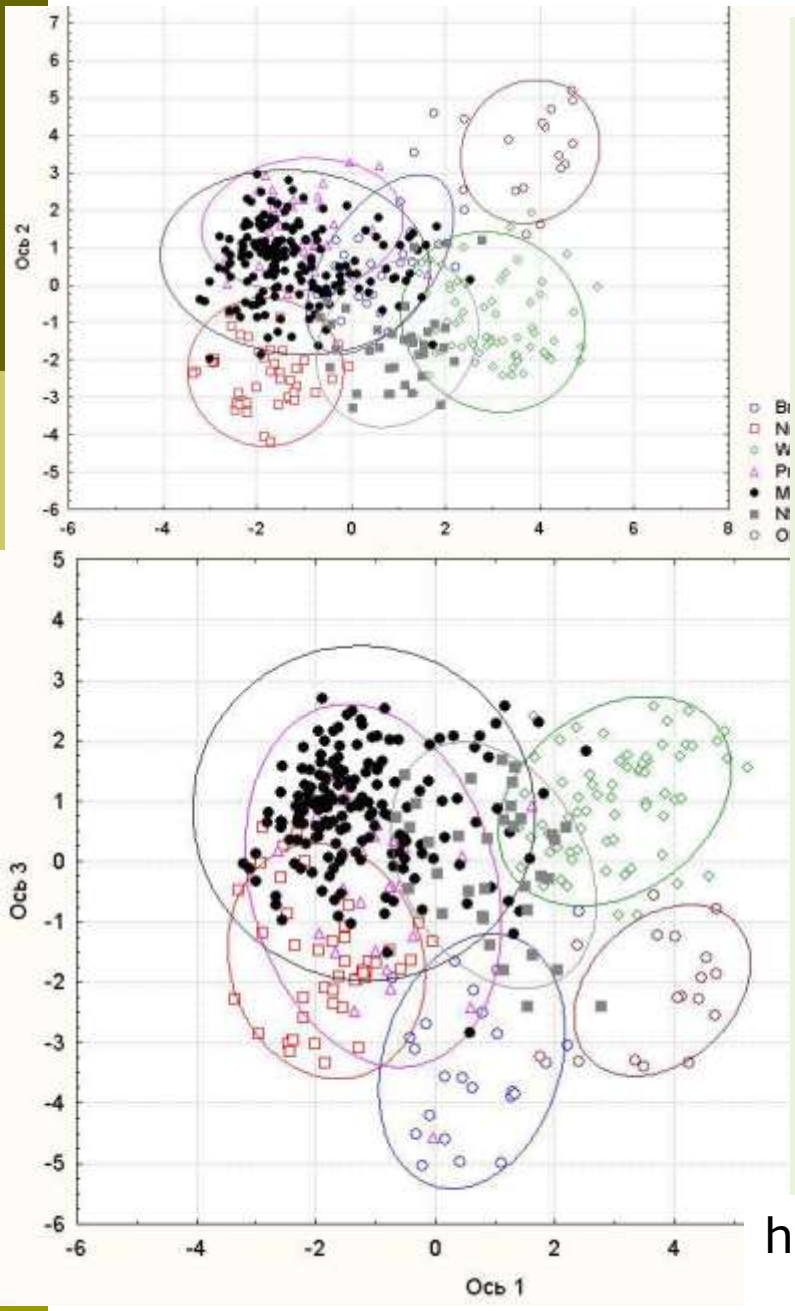
Species of oligotrophic bogs

Only 7 main groups with ab.

10 subgroups

Water-marsh species

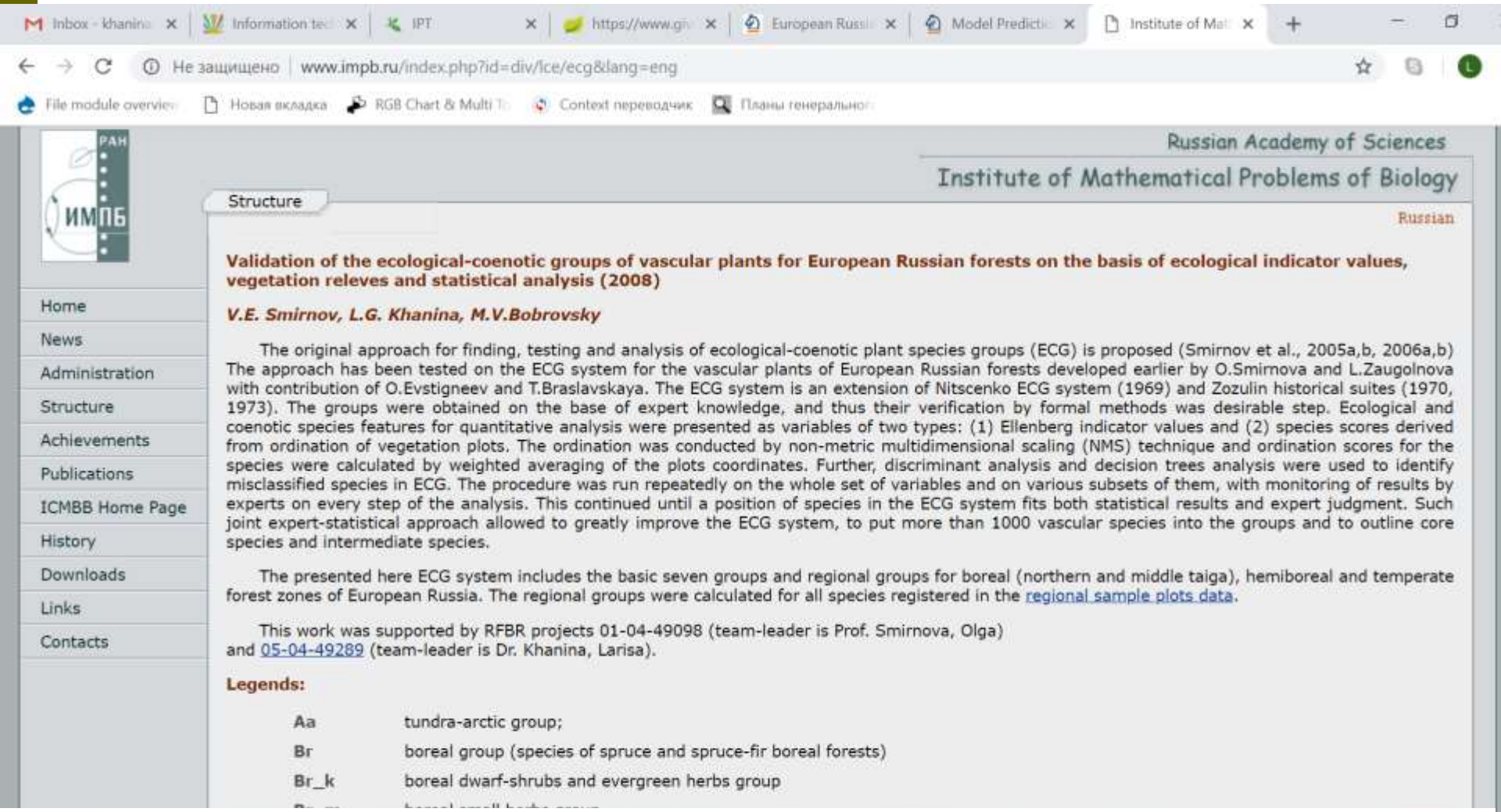
The composition of the ECG



(1) defined by experts (Nitcenko, 1968, Smirnova & Zaugolnova, 2001, Smirnova et al., 2004), and
(2) verified by discriminate analysis and decision tree techniques (Smirnov et al., 2006) using

- Ellenberg's indicator values (1991) and
- species ordination scores produced by NMDS of more than 3000 phytosociological relevés from European Russian forests

http://www.impb.ru/index.php?id=div/lce/ecg



1165 vascular plant species were divided into 7 main groups

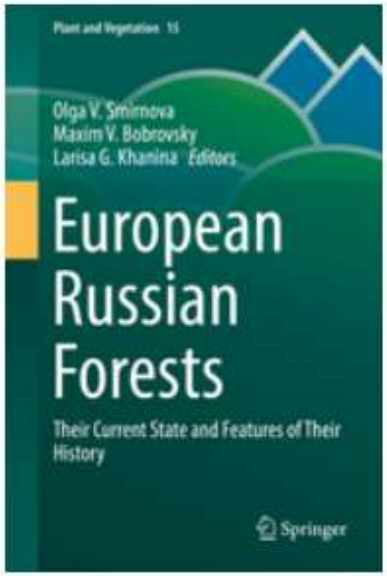
Typical species of the ECGs

1. the boreal group (Br) *Vaccinium myrtillus, Linnaea borealis*, *Lycopodium annotinum*, *Gymnocarpium dryopteris, Luzula pilosa, Maianthemum bifoluum, Oxalis acetosella,*
2. the nemoral group (Nm) *Aegopodium podagraria, Asarum europaeum, Convallaria majalis*, *Dryopteris cartusiana, Lathyrus vernus, Melica nutans, Milium effusum*, *Pulmonaria obscura*;
3. the nitrophilous group (Nt) *Filipendula ulmaria, Thalictrum minus, Trollius europaeus, Veratrum lobelianum, Veronica longifolia*;
4. the piny group (Pn) *Antennaria dioica, Vaccinium vitis idaea, Arctostaphylos uva-ursi, Calluna vulgaris, Veronica officinalis*;
5. the meadow-edge group (Md) *Dactylis glomerata Dianthus superbus, Elytrigia repens, Festuca ovina, Pulsatilla patens, Thymus serpyllum, Lathyrus pratensis, Knautia arvensis*;
6. the water-marsh group (Wt) *Caltha palustris, Carex vesicaria, Equisetum fluviatile, C.elongata, C.cespitosa*;
7. the oligotrophic group (Olg) *Carex globularis*, *Eriophorum vaginatum, Ledum palustre, Oxycoccus palustre, Vaccinium uliginosum*

Ecological-coenotic groups (ECGs) of plants

» Life Sciences » Forestry

Plant and Vegetation



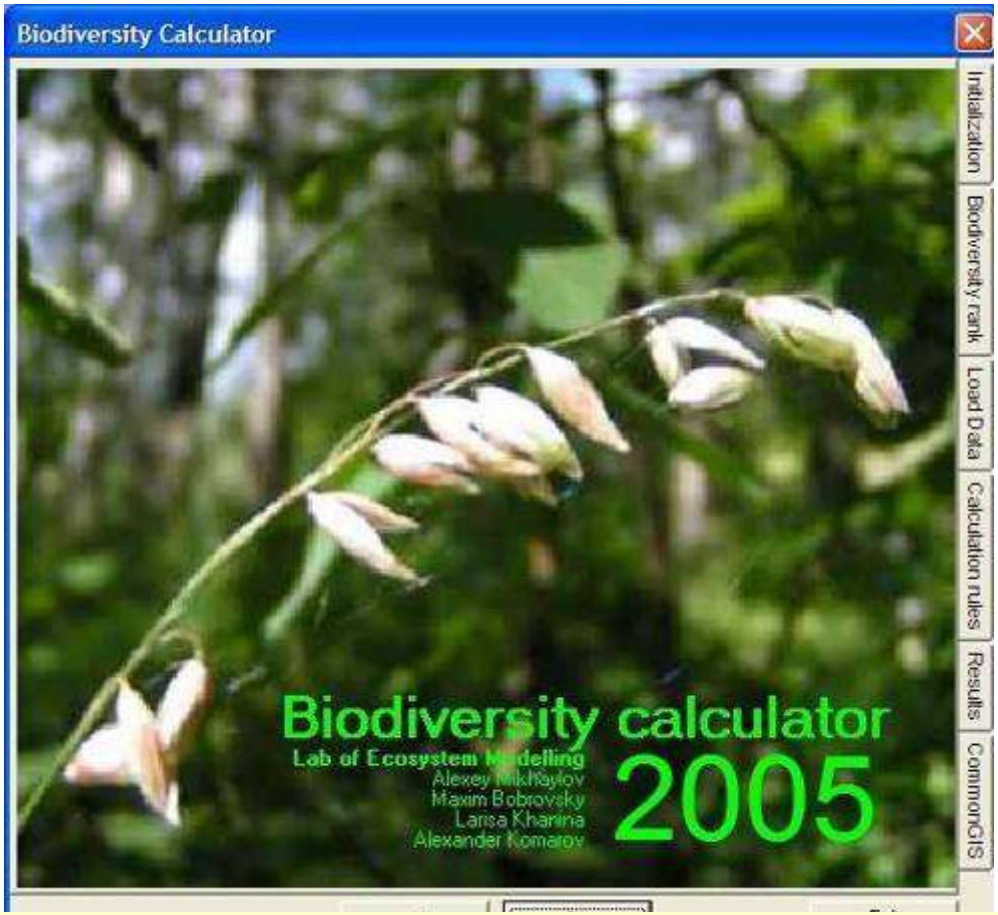
European Russian Forests

Their Current State and Features of Their History

Editors: **Smirnova**, Olga V., **Bobrovsky**, Maxim V., **Khanina**, Larisa G. (Eds.)

ECGs were used in forest typology and in estimation of structural diversity of vegetation

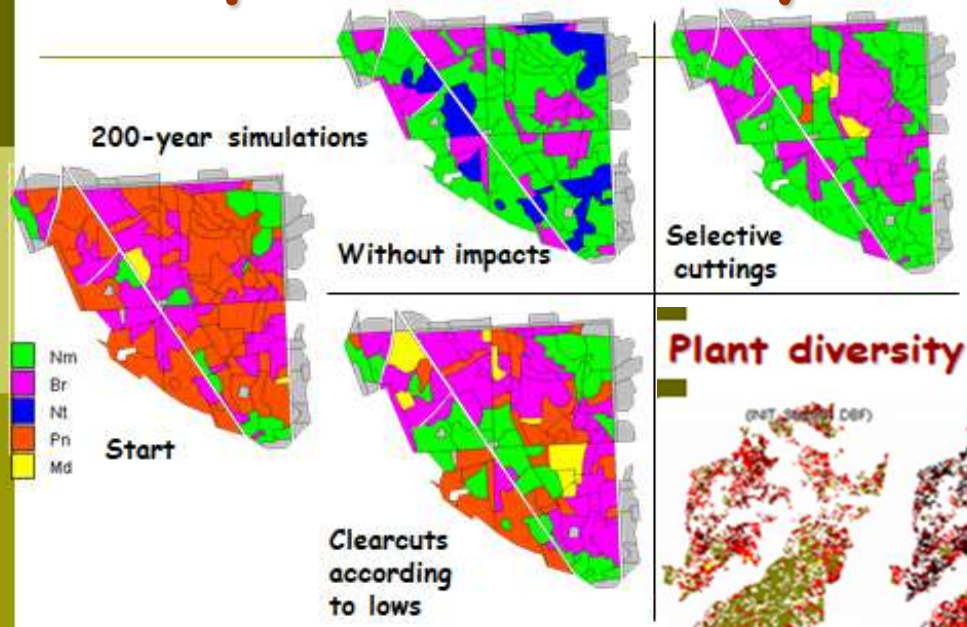
BioCalc – software to calculate dynamics of ground vegetation diversity. Applied with the models EFIMOD, ROMUL, FORRUS

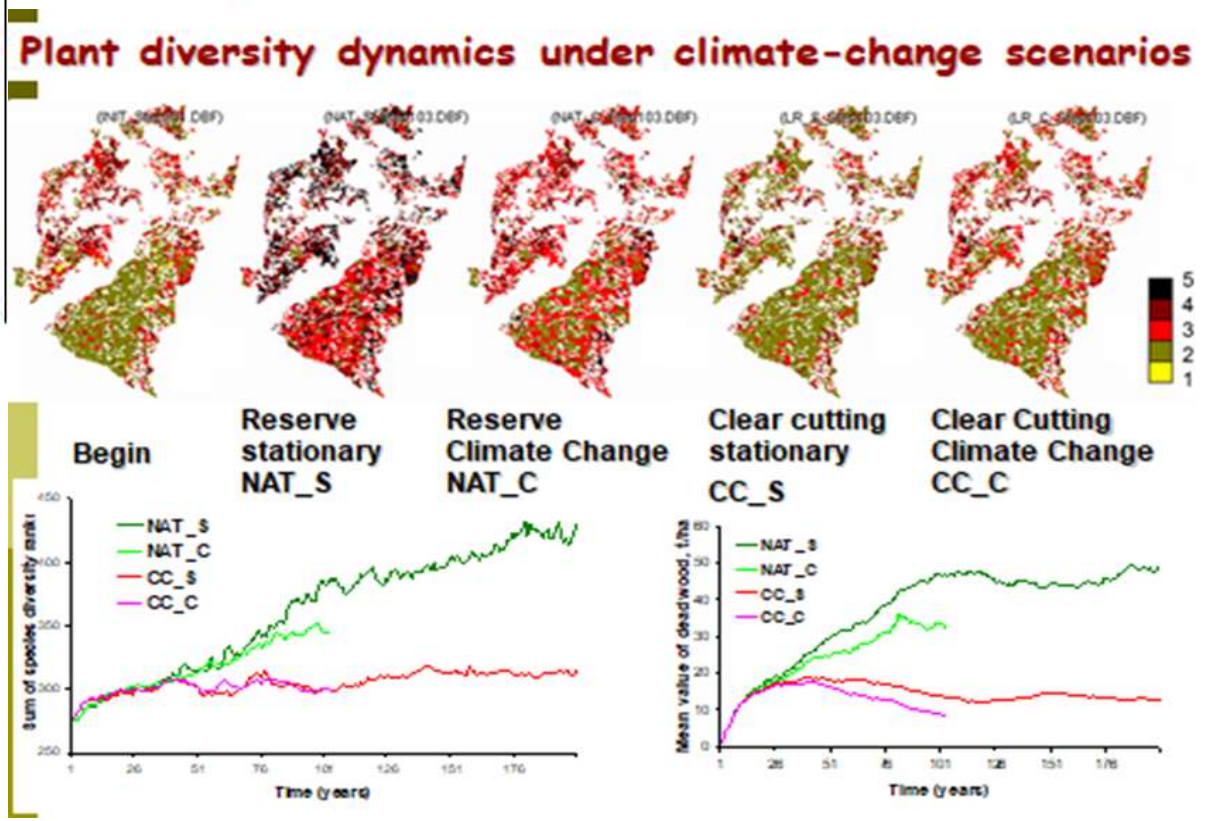


Seven ECG were used to modelling dynamics of species richness and structural diversity of ground layer of forest vegetation under 4 forest management regimes and 2 climate change scenarios

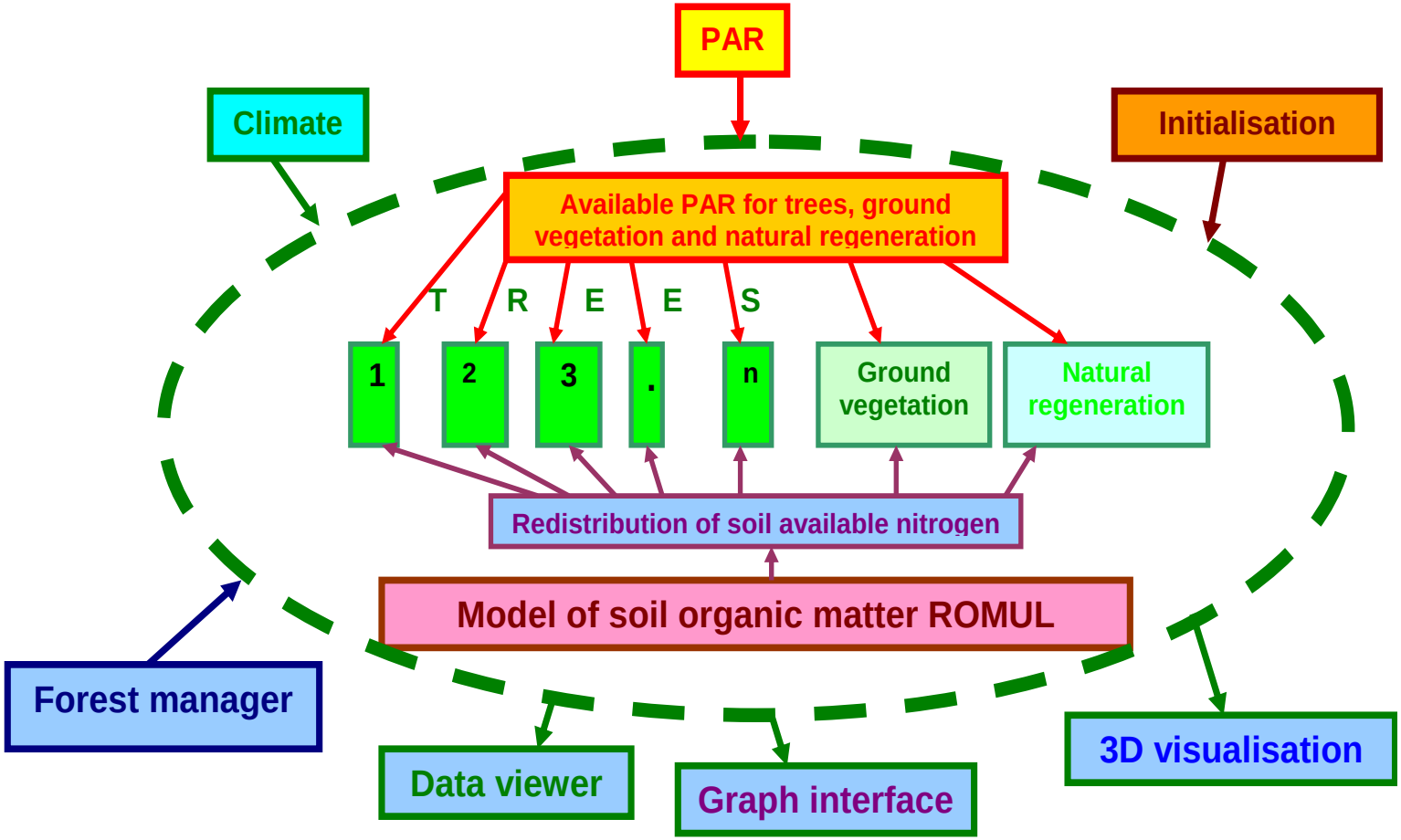
Khanina et al., For. Ecol. Manage. 2007: 80-94
Khanina et al., 2014. Nitrogen Deposition, Critical Loads and Biodiversity: 173-182

Examples of the simulated ECG dynamics and plant diversity assessment





Plant functional groups for carbon and nitrogen cycle modelling in forest ecosystems



in a frame of the EFIMOD model
(Komarov et al., 2003 and many others)

Functional groups in forest ground vegetation for the cycles modelling

Combination of Ecological-Coenotic Groups and Life Form Plant Traits:

- Lichens
- Mosses
- Herbs which fall in the end of vegetative season
  - Small herbs and small ferns
  - Tall herbs and large ferns
  - Grasses
- Evergreen herbs separated along to fall regime
- Deciduous dwarf shrubs
- Evergreen dwarf shrubs

Functional groups in forest ground vegetation for the cycles modelling

Combination of Ecological-Coenotic Groups and Life Form Plant Traits

- **Biomass and productivity of plant species**
- **Chemical composition**
- Rate of decomposition
- Nutrient, water and light species' supplies

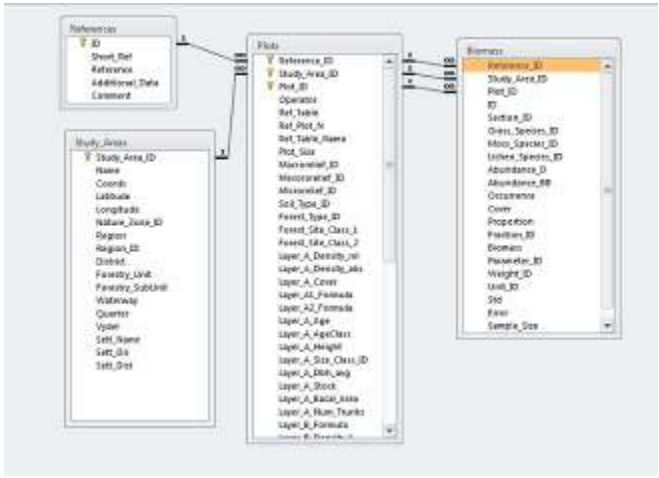
Databases

biomass of species and groups of species

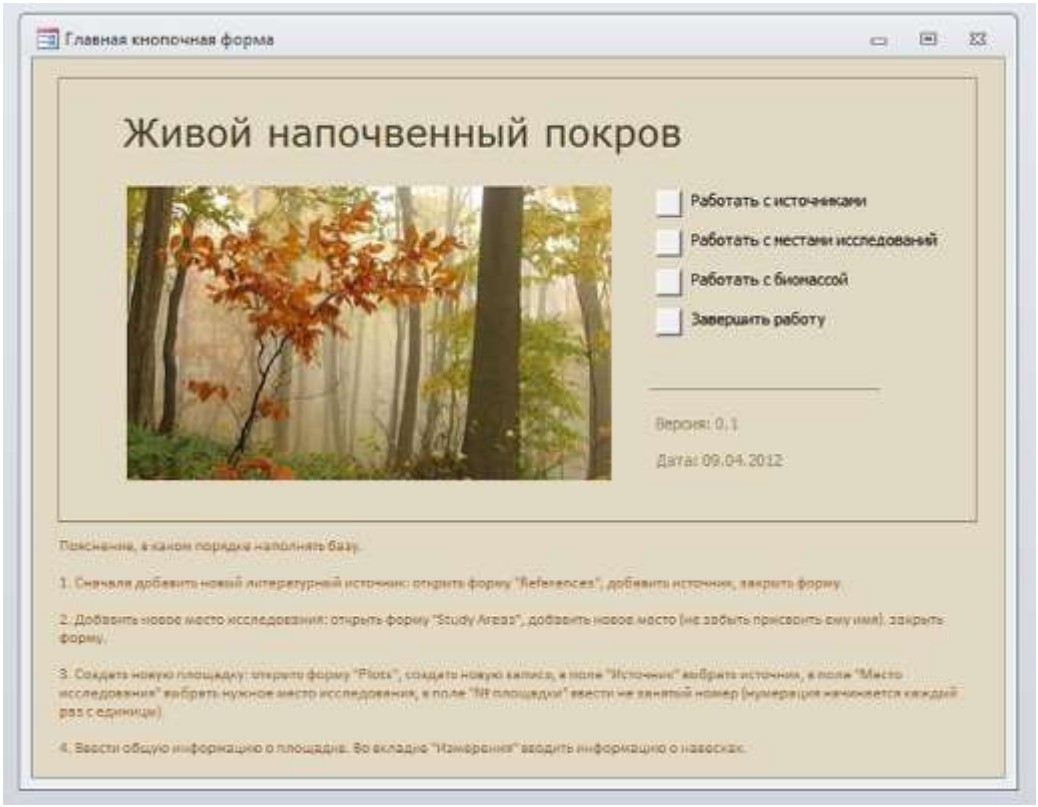
chemical composition of plants

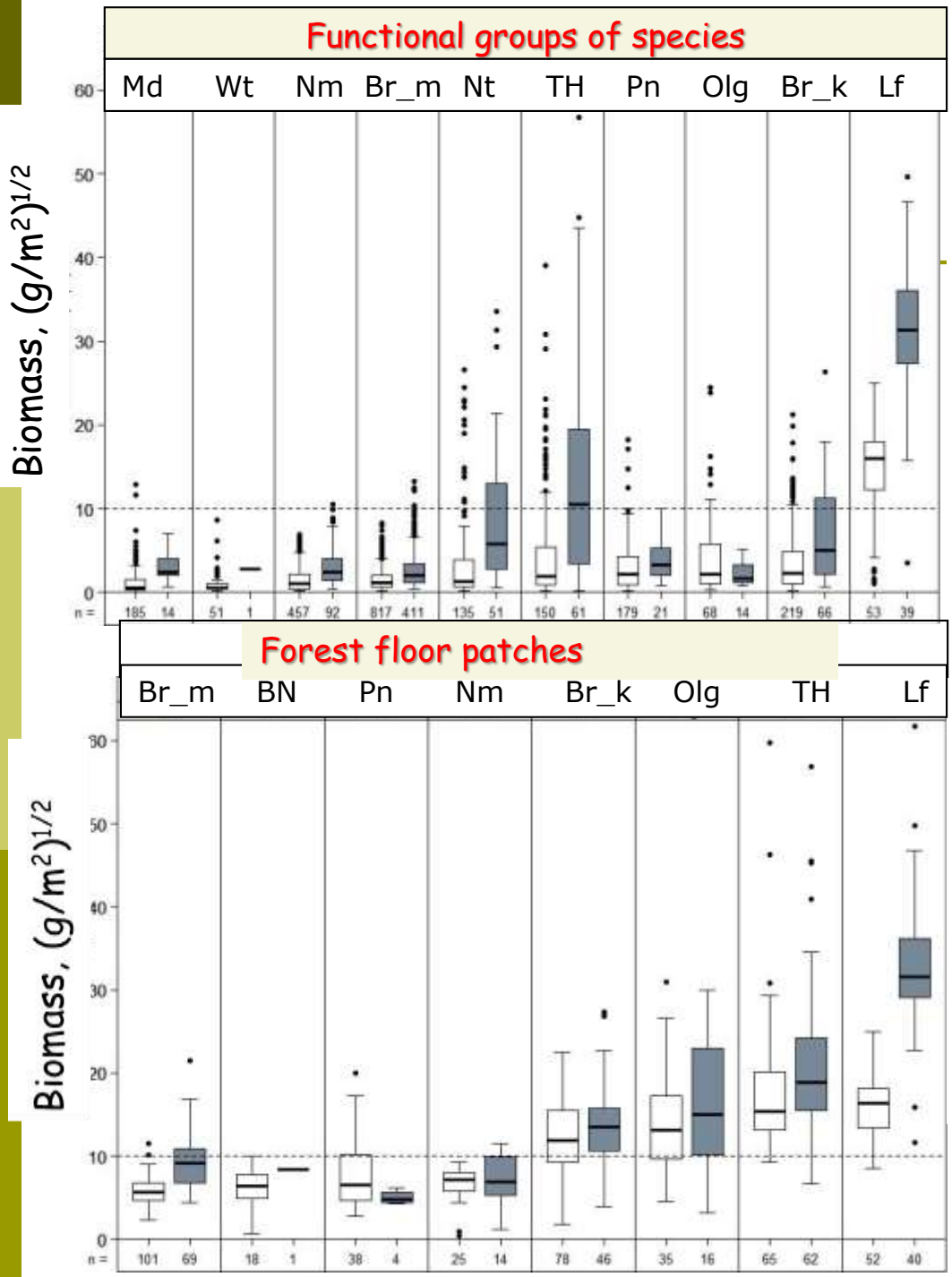
BIOMASS – a database on forest ground vegetation's biomass

Data sources – 79 scientific publications and original field data. More than 7000 records. 231 species. 103 study areas.



28 tables: 7 main frames,
18 reference tables, 3 flora lists





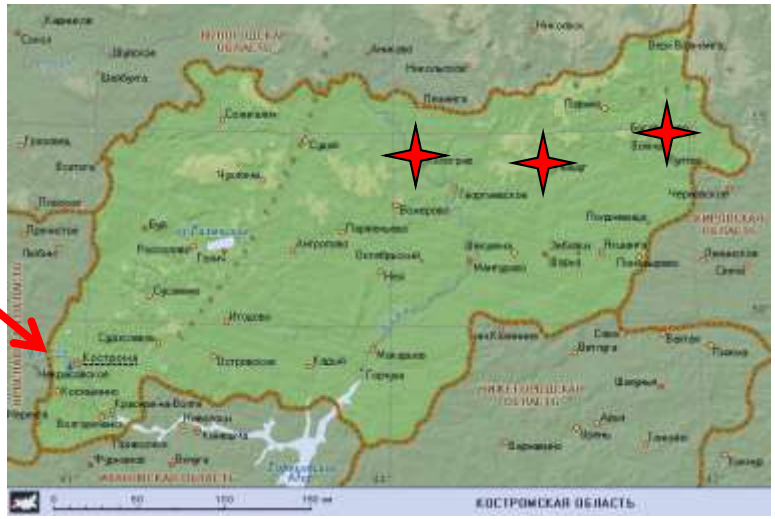
Forest floor patches were marked by the domination of FG in the plots

- Forest floor patches dominated by FG were better differed by the biomass values of vascular plants than by FGs
- Below-ground biomass was higher than above-ground biomass
- FGs and patches were better differed by below-ground values

Comparison of literature and experimental (field) data on plant biomass

Uneven-aged forests dominated by *Picea abies* and *Abies sibirica* with *Tilia cordata* in the hemiboreal forest region.

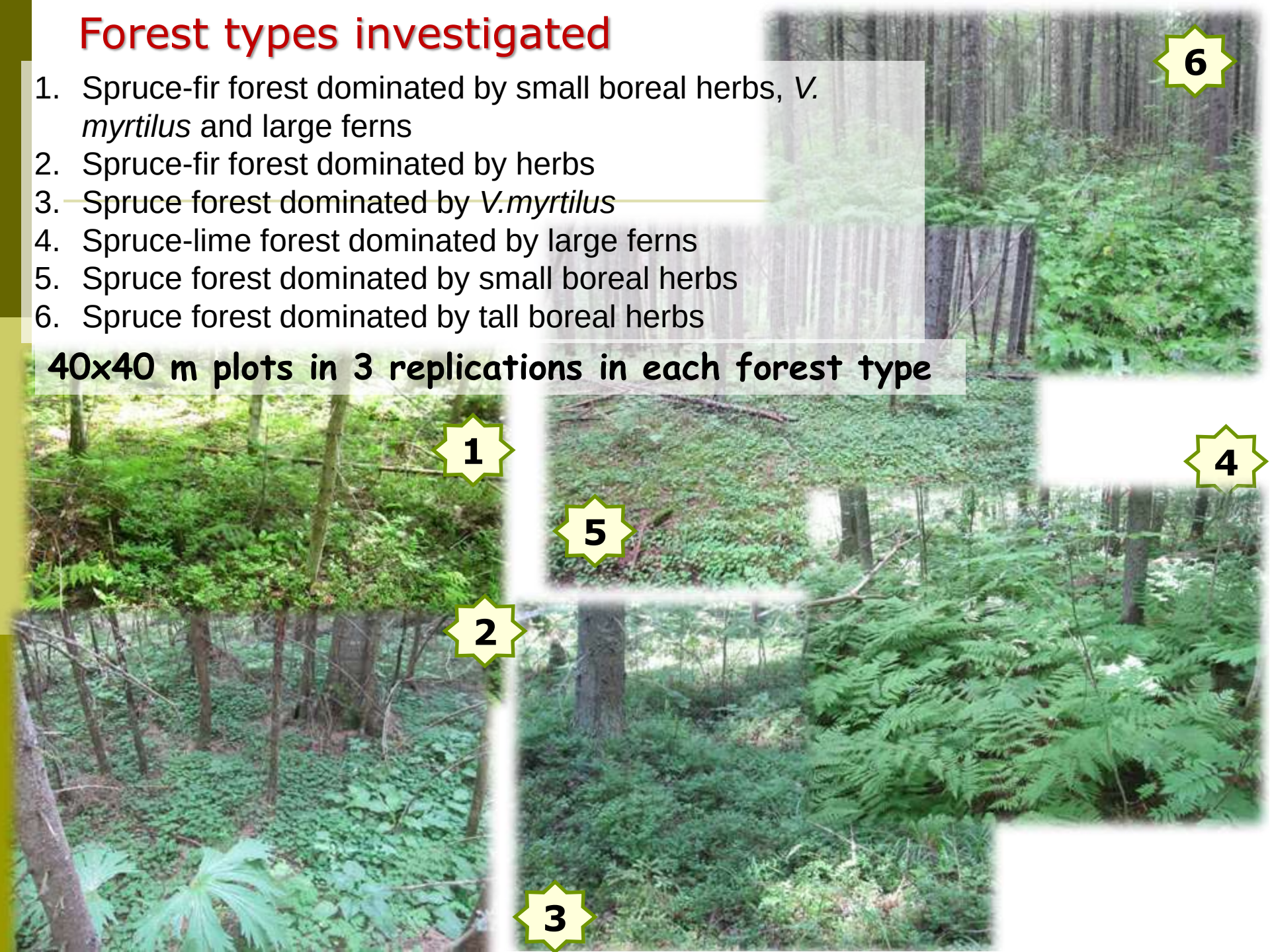
Kostroma administrative region (Irina Grozovskaya's data)



Forest types investigated

1. Spruce-fir forest dominated by small boreal herbs, *V. myrtilus* and large ferns
2. Spruce-fir forest dominated by herbs
3. Spruce forest dominated by *V.myrtilus*
4. Spruce-lime forest dominated by large ferns
5. Spruce forest dominated by small boreal herbs
6. Spruce forest dominated by tall boreal herbs

40x40 m plots in 3 replications in each forest type



Small boreal herbs & ferns (Br)

Forest floor patches

25x25 cm,
in 3 replications.
Totally 45 plots

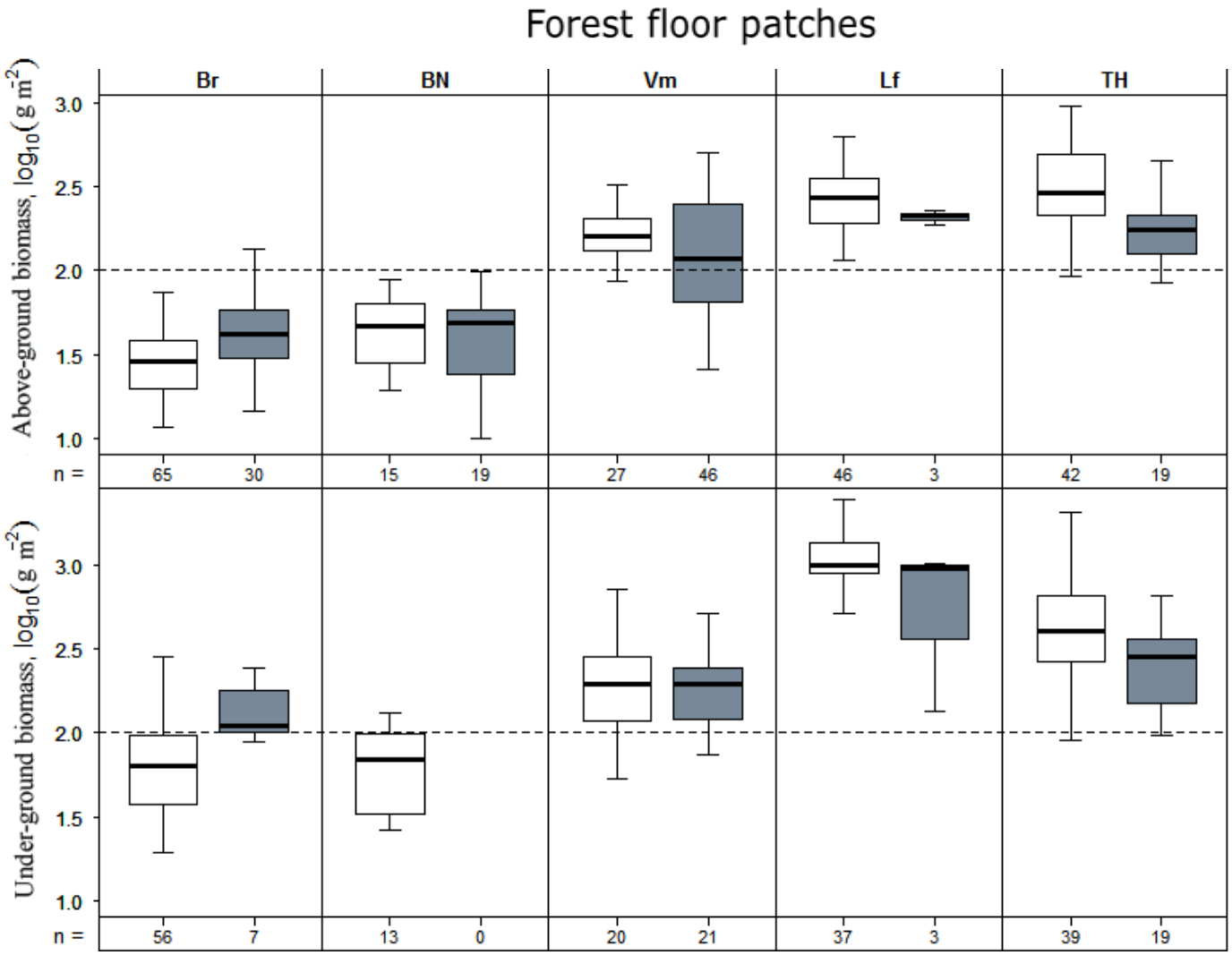
Large ferns (Lf)

Boreal-nemoral plants (BN)

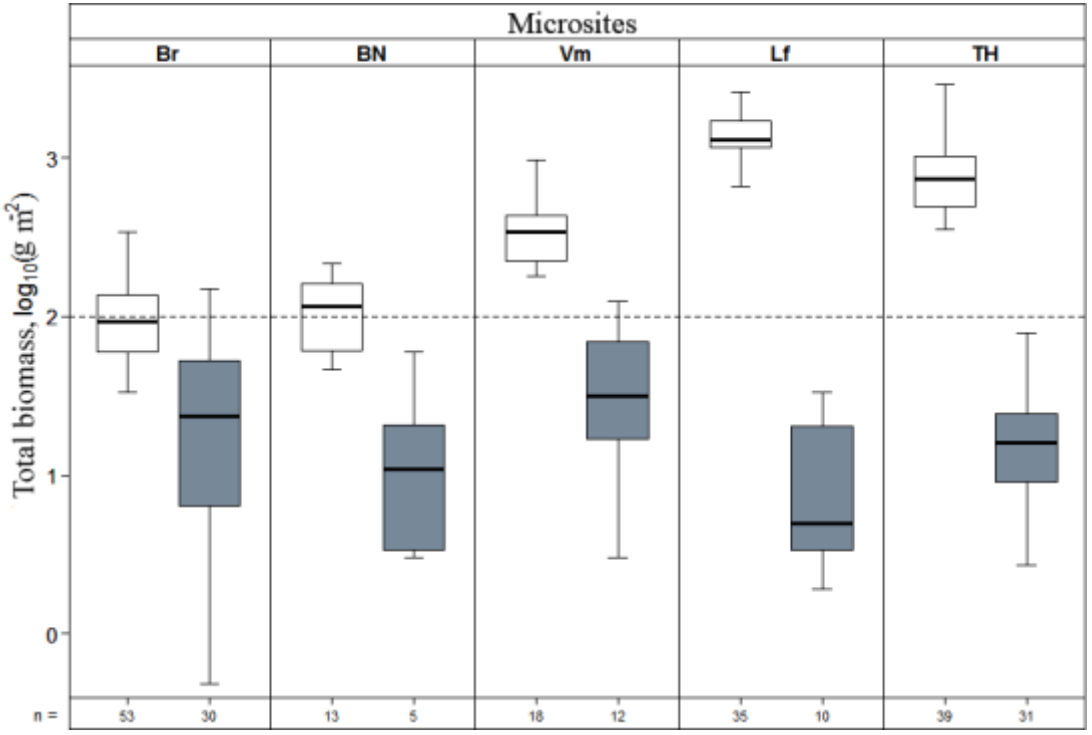
Tall boreal herbs (TH)

Boreal dwarf-shrubs (Vm)

Above- and below-ground biomass of vascular plants along to experimental (white) and literature (grey) data



Experimental data on forest floor patches: total biomass of vascular plants (white) and mosses (grey)



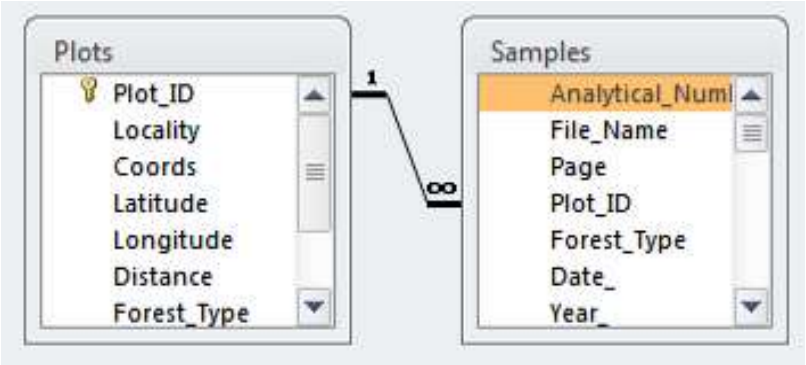
A forest type and a forest floor patch were significant factors, but the input of the forest floor patch was the highest

Forest floor patches dominated by species of different FG turned out to be the best factors differing the biomass of ground layer vegetation

Three-way nested ANOVA

Source of var.	Above-ground		Below-ground	
	VC, %	P	VC, %	P
Forest type	30.0	0.001	17.3	0.004
Floor patch	60.7	0.000	70.5	0.000
Error	9.3		12.2	

ELEMENTS – a database on plant species chemical composition



- Place and time of sampling
- Species and its fractions
- Chemical composition, mg/kg

Original data from Center for Forest Ecology and Productivity of RAS & Institute of Applied Ecological Problems in the North of Kola SC of RAS

More than 2500 samples, 80 species

N, C, Ca, Mg, Na, K, Al, Fe, Mn, Zn, Ni, Cu, P, S, Zn

Northern and middle taiga area, boreal forest region

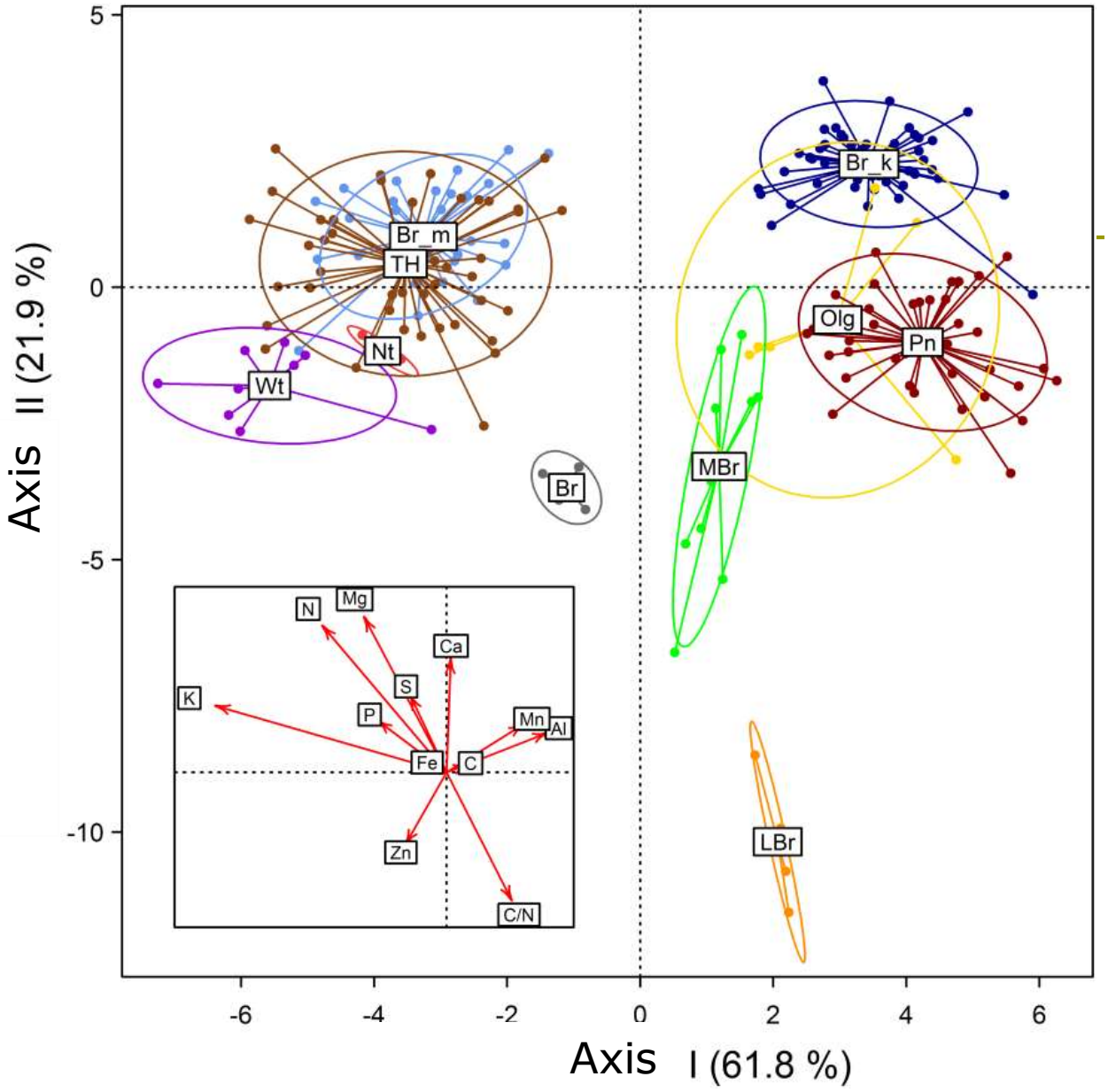
Polluted area mainly

We selected **542 samples, 68 species** (or group of species) from "the clean areas"

Cu, Ni < 5 mg/kg

Species Functional Groups analyzed by the ELEMENTS database (boreal forest region)

1) Lichens
2) Mosses
3) Small boreal herbs
   Equisetum sylvaticum, Gymnocarpium dryopteris, Maianthemum bifolium, Oxalis acetosella, Phegopteris connectilis, Rubus saxatilis, Trientalis europaea
4) Tall boreal herbs
   Aconitum septentrionale, Athyrium filix-femina, Cacalia hastata, Chamaenerion angustifolium, Crepis sibirica, Diplazium sibiricum, Dryopteris carthusiana, D.dilatata, Geranium sylvaticum, Paeonia anomala, Rubus idaeus
5) Boreal grasses (*Avenella flexuosa*)
6) Boreal dwarf shrubs (deciduous dwarf shrubs and ever-green herbs)
   Vaccinium myrtillus, Lycopodium sp.
7) Piny dwarf-shrubs (evergreen dwarf-shrubs) *V.vitis-idaea*
8) Nitrophilous large herbs *Cirsium oleraceum, Filipendula ulmaria*
9) Oligotrophic ever-green and deciduous dwarf-shrubs
   Empetrum hermaphroditum, Ledum palustre, V.uliginosum
10) Water-marsh plants
   Calamagrostis phragmitoides, Eleocharis sp., *Phragmites* sp., *Scirpus* sp.
11) Intra-water plants



Linear Discriminant Analysis of 204 records from the ELEMENTS database. 39 species, 10 FG

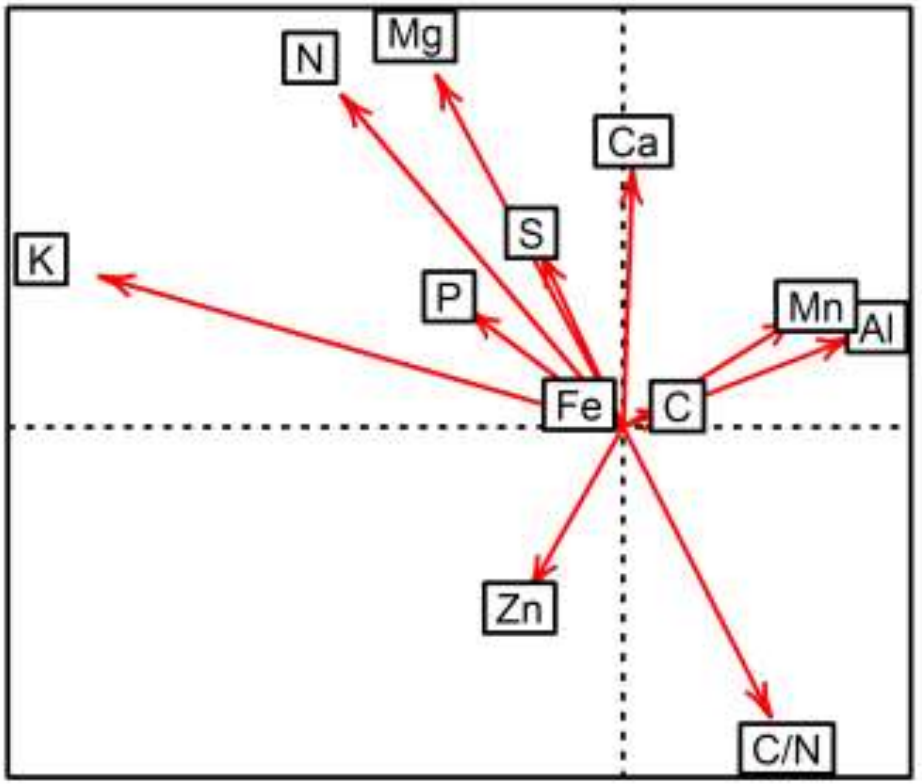
Wt – water-marsh species,
Nt – nitrophilous species,
TH – tall boreal herbs,
Br_m – small boreal herbs,
Br – *Avenella flexuosa*,
MBr – boreal mosses,
Br_k – boreal dwarf-shrubs,
Olg and Pn – oligotrophic and piny dwarf-shrubs,
LBr – boreal lichens

More than 88% of the objects were well classified.
First two axes explained ab.84% of the intergroup dispersion

Std. canonical coeff. for two first can.variations

	Can.Var. 1	Can.Var. 2
C/N	1.84	5.08
N	1.79	3.46
K	–1.30	0.07
C	–0.95	–2.69
Mn	–0.01	–0.72
Al	0.91	–0.27
Ca	0.52	–0.42
Fe	–0.56	0.33
P	0.51	0.05
S	0.08	–0.17
Zn	–0.21	0.34

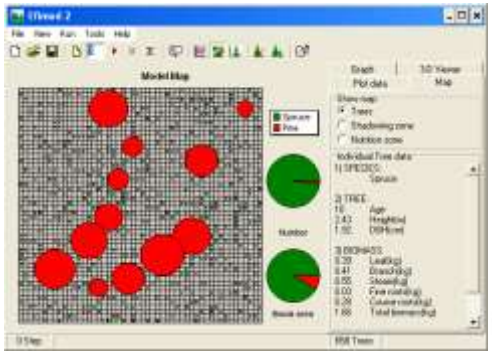
Factor loads

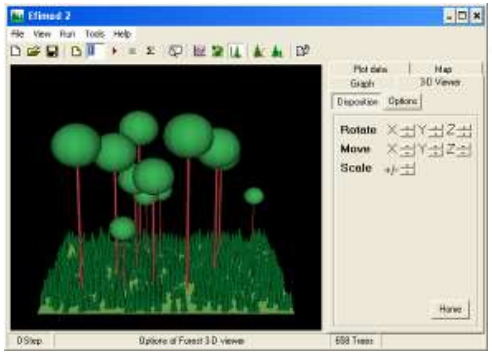


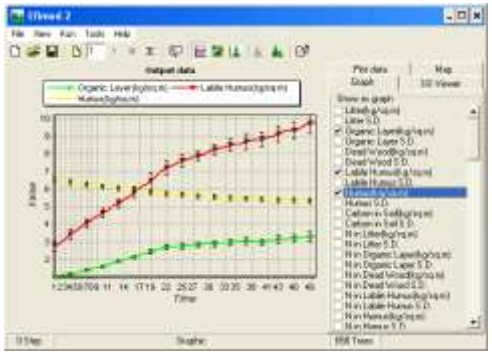
Analysis of BIOMASS & ELEMENTS databases

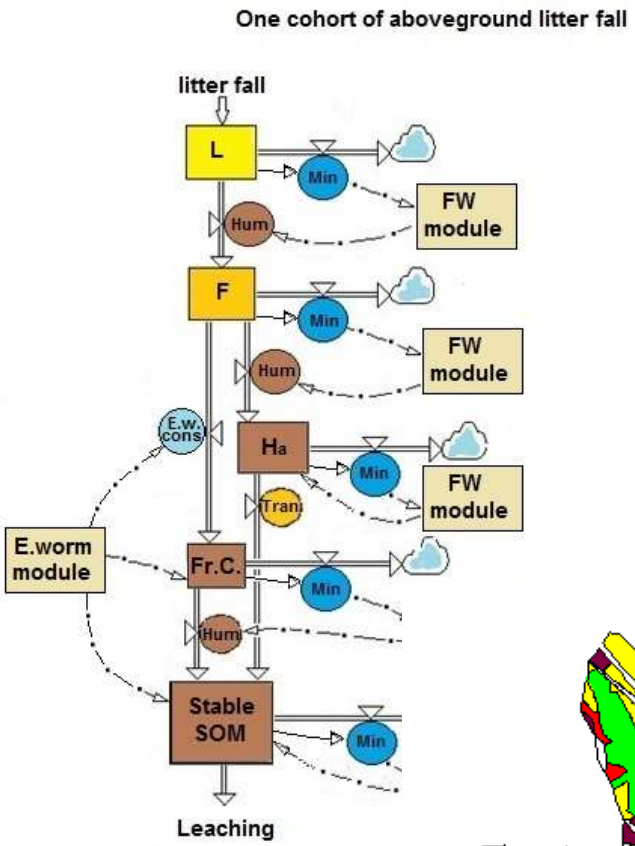
- Forest floor patches dominated by the proposed FG are well differed by the biomass values
- Species belonging to the one FG have similar values on the content of the main chemical elements
- The patterns allow the developing the approach to simulate ground vegetation dynamics by the changing proportions of different patches contributed to the biogeochemical cycle in forest ecosystems

System of models:
Romul (soil) + EFIMOD (trees)



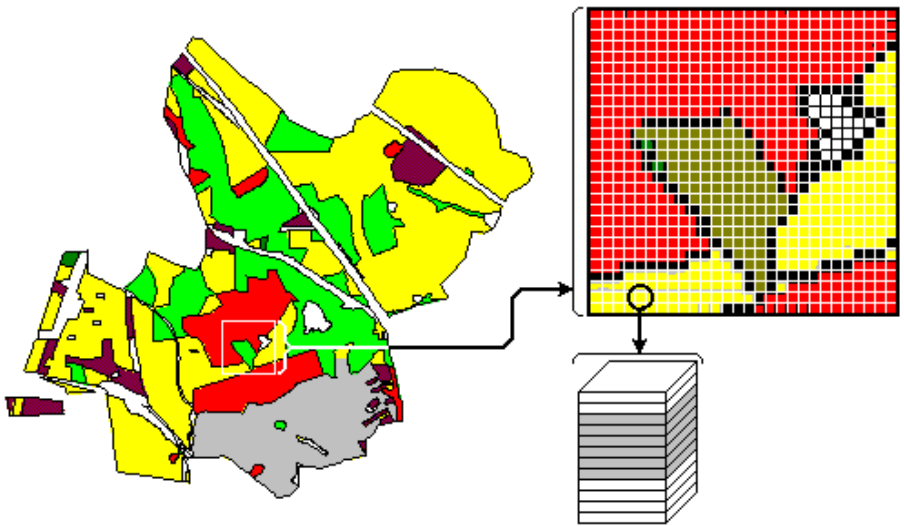




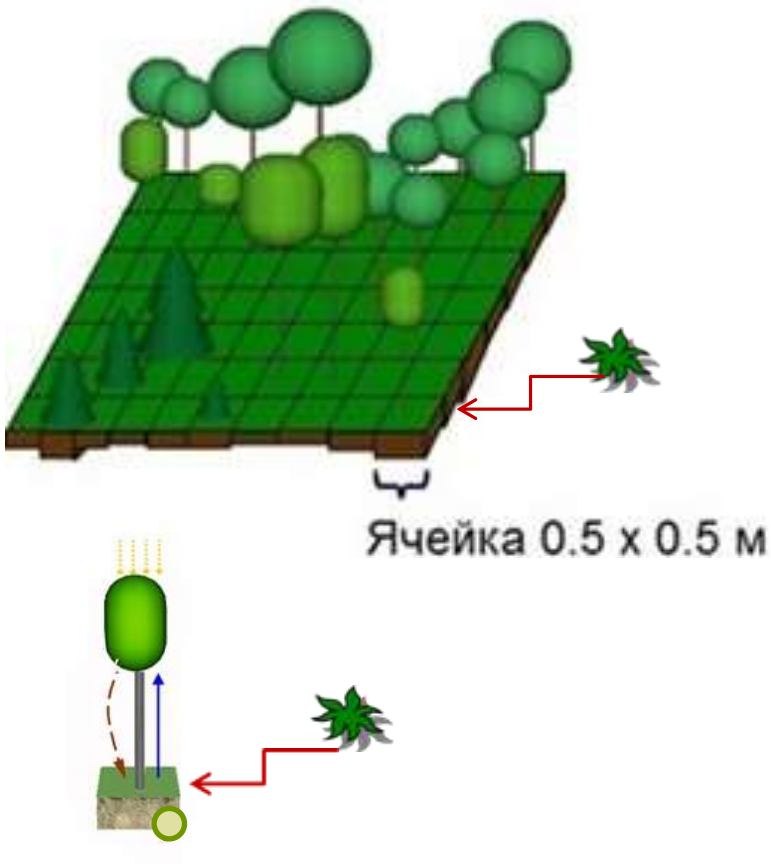


or
Romul-HUM (Chertov et al., 2017: Romul + SoilFoodWeb & E.worm) +

FORRUS (Chumachenko et al., 2003)



Dynamics of forest ground vegetation



In the EFIMOD model, a cell for tree modelling is 0.5 x 0. 5 m

Spatial unit for ground vegetation modelling is a forest floor patch dominated by one or two FG

Forest floor patch in the model is proposed to be of the same size 0.5 x 0. 5 m

Parameters of the EFIMOD+ROMUL unit is changing at each simulated step (1 year) and ground vegetation will be also changed with feedback to ROMUL and then to EFIMOD

Conclusion

- We have proposed a system of Functional Groups of plant species from ground layer of forest vegetation for modelling nutrient and carbon cycles in forest ecosystems
- Forest patch dominated by FG of plants are well differed in their biomass values
- Species belonging to a particular FG had similar values on the content of the main chemical elements
- We have proposed a conceptual model for ground vegetation dynamics which will be realized in a system of soil-forest biogeochemical cycle models (ROMUL - EFIMOD or Romul-HUM - FORRUS)

Development and analysis of the database “Elements” was supported by the Russian Science Foundation, project №16-17-10284

The results were received under the POLYFORES project:
Decision-making Support for Forest Ecosystem Services in Europe - Value Assessment, Synergy Effects and Trade-offs (FP7 ERA-NET Sumforest)

THANK YOU VERY MUCH FOR YOUR ATTENTION!